GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. _____

Project No. B-10-647 (SEE BELOW) GTRC/~~GIT~~ DATE 7 /22 / 85

Project Director: Dr. Bernd Kahn School/~~Lab~~ OIP

Sponsor: U. S. Department of the Interior, Geological Survey, 12201 Sunrise Valley Drive, MS205C, Reston, VA 22092

Type Agreement: Grant No. 14-08-0001-G-1011

Award Period: From 6/6/85 To ~~6/30/86~~ 6-30-86 (Performance) 6/30/86 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated: $		$ 109,000
Funded: $		$ 109,000

Cost Sharing Amount: $ 68,990 (GIT portion) Cost Sharing No: B-10-315, E-20-396, E-20-397, E-20-398

Title: 1985 State Water Resources Research Institute Program

ADMINISTRATIVE DATA OCA Contact Don S. Hasty

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Defense Priority Rating: N/A Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

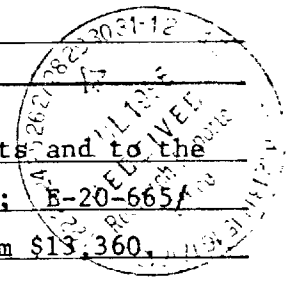
See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with N/A – none proposed. Reference par F.5 for later acquisition of equipment.

COMMENTS:

Portions of this Grant are being allocated both to other GIT Departments and to the University of Georgia. Subprojects to GIT are: B-10-647/Kahn $28,038; E-20-665/Georgakakos $13,360; E-20-668/Gould & Kaudenko $13,169; E-20-670/Sturm $13,360.



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Accounting	Research Communications (2)	Other _____

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 10/30/86

Project No. B-10-647 School/~~Lab~~ OIP

Includes Subproject No.(s) E20-665/Georgakakes; E20-668/Gould & Khudenko; E20-670/Sturm

Project Director(s) Dr. Bernd Kahn GTRC / ~~GIT~~

Sponsor U.S. Dept. of Interior, Geological Survey

Title 1985 State Water Resources Research Institute Program

Effective Completion Date: 6/30/86 (Performance) 8/31/86 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions - Questionnaire sent to P.I.
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. B10-637 Continued by Project No. B10-660

COPIES TO:

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A. Jones
R. Embry

FORM OCA 69 285

FISCAL YEAR 1985 PROGRAM REPORT

Water Resources Research Institute
Georgia Institute of Technology
Georgia

Report No.
G1011

Fiscal Year 1985 Program Report
Grant No. 14-08-0001-G1011

for

U.S. Department of the Interior
Geological Survey

by

Environmental Resources Center
Georgia Institute of Technology
Atlanta, GA. 30332

Bernd Kahn, Director
August 1986

The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Georgia Water Resources Research Institute.

ABSTRACT

The FY 1985 Program included the following six research projects:

Correlation Detectors for Selective Detection of Pollutants in Natural Waters, by J.L. Anderson. Application of coupled electrochemical and spectrophotometric detectors for extremely sensitive analysis of certain organic compounds in water is being developed by testing a mathematical simulation model, evaluating electrode arrays, and checking the predicted response of the detectors.

Instantaneous Unit Hydrographs: A Geomorphologic Approach, by A.P. Georgakakos. For streamflow forecasting, watershed response to rainfall was modelled as a continuous time Markov process, including both surface and subsurface runoff.

Cadmium Recovery from Wastes by Cementation on to Magnesium, by J.P. Gould and B.M. Khudenko. Effective removal of soluble cadmium salts from waste water was demonstrated by reduction to elemental cadmium with magnesium metal.

A Statistical Analysis of Several Facets of Low Stream Flow Distributions, by W.P. McCormick and J.H. Reeves. A general solution is presented for obtaining an asymptotic expression for the sampling distribution on which the 7Q10 value is based.

Evaluation of User Charges to Finance Water Projects, by R.M. North, J. Sellers, and J.O. Smith. Existing funding and repayment information is presented, selected cases that demonstrate application of promising mechanisms are described, and new mechanisms and pricing structures are proposed.

Alluvial Streambed Degradation, by T.W. Sturm. Streambed adjustments by scour and fill were predicted with a numerical model and observed in a physical laboratory model.

This research was performed at the Georgia Institute of Technology and the University of Georgia in the period June 1985 - June 1986, with funds provided by the U.S. Geological survey and the Georgia Board of Regents. Technical completion reports for these projects are available in the Environmental Resources Center report series, # 01-86 to 06-86. The research, with related student training and information transfer, is managed by the Environmental Resources Center as part of its activities as the Water Resources Research Institute for Georgia under the Water Resources Research Act of 1984 (PL 98-242).

Keywords: *Research, *Information Transfer, *Training, *Georgia, *Water Analysis, *Electrochemistry, *Spectrophotometry, *Unit Hydrographs, *Low-Flow Frequency, *Flood Forecasting, *Cadmium, *Waste Water Treatment, *Design Flow, *Streamflow Forecasting, *Financing, *Pricing, *User Rates, *Cost Sharing, *Water Rates, *Cost Allocation, *Bed Load, *Sediment Distribution, Extreme Value Theory, Cementation

TABLE OF CONTENTS

WATER PROBLEMS AND ISSUES OF GEORGIA

Periodically, a serious drought focuses the attention of both the general public and water management professionals on the adequacy of the water supply. This situation recently occurred in Georgia (and adjoining states in the southeastern U.S.), where essentially no rain fell from March through July of 1986, with rainfall to date of approximately one half of the normal 30 inches. By the end of July, crops that depend on rainfall had suffered serious damages, barge traffic had been halted on the lower reaches of the Chattahoochee River, a number of shallow wells had run dry, and significantly lower levels in several impoundments operated by the U.S. Corps of Engineers had closed marinas and reduced recreational use. Some municipalities that depend on flowing water for their supplies had to adjust their intake systems in response to lower stream levels, and municipalities with water supplied by impoundments or deep wells prepared for a long drought by limiting nonessential water use.

In response to this situation, water users are developing long-term plans for more reliable water supplies from surface water impoundments or deep aquifers, the former generally above the Fall Line in Georgia, and the latter below it. The Institute program previously addressed this issue by including several research projects for obtaining alternate or expanded supplies, notably report ERC 01-86 (see List of Publications). The magnitude of the present drought is so unusual, however, that responses directed to a limited number of supplies that have not kept pace with demand are expected to be sufficient to assure supplies under most circumstances.

Although in more typical years the supply of water is plentiful for the state as a whole, its distribution does not exactly match needs for consumption or dilution, hence serious efforts must be devoted to using the existing water wisely and planning for future growth. Pumping groundwater for industrial use near the coast resulted in some instances of saltwater intrusion several years ago, and a recent spurt in agricultural waterpumping in southwestern Georgia has raised concern about lowering water tables. The intensive farming associated with much greater water use also places more herbicides and pesticides into the environment as potential pollutants of ground and surface water. Erosion and sedimentation are problems of long standing in Georgia, where much of the topsoil from the Piedmont has moved toward the sea in its rivers.

Other water resources issues in Georgia are those of a state with sufficient rainfall and extensive rivers and aquifers, but with growing demand for water paralleled by a growing insistence on environmental quality. Construction and operation of water supply and wastewater treatment facilities require adequate financing; water quality protection requires monitoring, enforcement of liquid effluent and solid waste handling controls, reduction of non-point sources of pollutants, and guidance for treatment practices; and maintaining environmental quality requires an understanding of ecological processes and control over actions that have potentially adverse effects.

PROGRAM GOALS AND PRIORITIES

The Water Resources Research Institute is designated to function as research support for the state water management agency by mobilizing the faculty members with expertise in various aspects of water resources research at all universities and colleges in Georgia. The Institute maintains close contact with water agency staff to identify problems and issues; obtains guidance from an advisory committee of water resources professionals and concerned citizens in selecting problems susceptible to research at the available funding; invites research proposals from as many researchers as possible; and selects the most suitable projects on the advise of peer reviewers to constitute its annual program (for operational details, see below). The program for any year, therefore, will be shaped by the state needs, the Institute's list of priorities, the researchers within the state who are interested in participating in the program, the available financial support, and the quality of research proposals.

The priorities developed for FY 1985 are given in Table 1. Some of these research areas are of long standing and will continue to be on priority lists in years to come. Other research areas come to the forefront because of increasing demand for water, natural or man-made changes in the environment, and attention focused by pressing problems, expressed concerns or new regulations. The Institute attempts to achieve a balance between research of long-term and immediate interest within available resources.

The six projects undertaken in the FY 1985 program addressed the following priorities:

- Predicting low stream flows (projects 03 and 05)
- Methods of tests for toxic and hazardous materials (project 02)
- Sedimentation in lakes and streams (project 07)
- Industrial and municipal wastewater treatment (project 04)
- Financing water development and use (project 06).

Brief descriptions are given below and more detailed synopses follow this section. The first, second, and fourth of these topics had been the subject of research by other investigators during the previous year (see List of Publications).

Project 02 pursued a current trend in attempting to reach ever lower detection levels for organic contaminants in water. One successful approach combines two different analytical processes to distinguish one compound or class of compounds from others. In this instance, electrochemical and spectrophotometric detectors were combined by J.L. Anderson. The mathematical simulation models needed for this approach were developed, an array of sensitive electrodes was tested to confirm the model, and detector response was evaluated for a range of conditions. The system is now ready for application.

Project 03 approaches stream-flow forecasting by modelling watershed response as a continuous-time Markov process to derive instantaneous unit hydrographs. The streamflow discharges respond to rainfall intensities

Table 1

Research Topics Recommended by the
Georgia Water Resources Research Program Development Committee
for FY 1985

Water quantity

Predicting low stream flows
Information on surface water/groundwater transfer
Groundwater flow modeling for multiple layers
Simple measurement of surface- and ground- water withdrawals
Effects of change to wastewater land application on low stream flow
Application of urban runoff infiltration and recharge

Water quality

Surface water quality mapping
Saltwater/freshwater interface mapping
Methods of test for toxic and hazardous materials in water
Delineation of pollution from agriculture and silviculture
Sedimentation of organic pollutants in groundwater
Industrial and municipal wastewater treatment

Water management

Comprehensive water use planning
Financing water development and use
Drought and flood control planning
Optimum use of hydropower
Value of wetlands

and both surface and groundwater runoff. Dr. A.P. Georgakakos demonstrated the model in a case study and plans additional case studies.

Project 04 demonstrated cementation onto magnesium as an effective means of removing cadmium salts from waste streams. The process reduces cadmium with magnesium metals so that cadmium salts form the insoluble metal while non-toxic magnesium dissolves in the wastewater. J.P. Gould and B.M. Khudenko determined rates and equilibrium distribution for the procedure at various pH and cadmium levels.

Project 05 considered low-flow steam prediction from a statistical point of view. W.P. McCormick and J.H. Reeves present a general solution for a sampling distribution, on which the 7Q10 value is based, for stream flow at the low end of the flow distribution. The investigators also consider monthly instead of annual 7Q10 values and how to estimate these values when stream flow data are incomplete.

Project 06 suggests innovative pricing arrangements to support construction and operation of water-related projects. R.M. North describes existing financing arrangements and their magnitude, identifies some potential alternative procedures, and proposes new approaches. Various pricing arrangements are considered and the effects are evaluated in case studies.

Project 07 determined streambed adjustments due to scour and fill theoretically, by mathematical model, and experimentally, in a physical laboratory model. For the mathematical model, T.W. Sturm solved the sediment continuity equation numerically by streamtube at several cross sections. The physical model confirmed some of the trends indicated by the mathematical model, but showed some weaknesses that will require refinements of the calculational approach.

While research for these projects was under way, the cycle of planning, project proposal evaluation, and program preparation for FY 1986 was begun. The FY 1986 program started in April, 1986, with the projects listed in Table 2.

Table 2

FY 1986 Water Resources Research Institute Program for Georgia

Title	Principal Investigator
Modeling Transient Ground Water Flow in Multilayer Aquifer Systems	Mustafa M. Aral Georgia Tech
Microcomputer Program for Estimating Drought Stream Flow Reduction Due to Wells	John F. Dowd and Kathryn J. Hatcher University of Georgia
Lateral Movement of Infiltrating Water in Layered Soils of the Southern Piedmont	David E. Radcliffe, William P. Miller, and Henry F. Perkins University of Georgia
Optimal Schemes for Ground Water Quality Monitoring in The Shallow Aquifer, Dougherty Plain, Southwestern Georgia	Shahrokh Rouhani Georgia Tech
The Analysis of Organic Contaminants in Water by High-Performance Liquid Chromatography with a Swept-Potential Electrochemical Detector	Peter E. Sturrock Georgia Tech
Evaluation of Subsurface and Outflow Quality from Drainage-subirrigation Systems in the Georgia Flatwoods	Daniel L. Thomas, Adel Shirmohammadi, and E. Dale Threadgill University of Georgia
Index to Georgia Water Data Files and Reports	Kathryn J. Hatcher University of Georgia

Research Project Synopses

SYNOPSIS

Project No.: 02 Start: 06/85
End : 06/86

Title: Correlation Detectors for Selective Detection of Pollutants in Natural Waters

Investigator: Anderson, James L., Department of Chemistry, University of Georgia, Athens, Georgia 30602

COWRR: 05A Congressional District: Fifth Georgia

Descriptors: Water analysis, correlation, electrochemistry, spectrophotometry

Problem and Research Objectives:

Selectivity in analytical detection methods is an important problem in environmental analysis. Frequently, the ability to detect a component of a complex environmental matrix is limited by the ability to distinguish that component from interfering species also found in the sample. One strategy to overcome this problem is to rely on multiple detectors for the component of interest. This project focused on the feasibility of coupling electrochemical and spectrophotometric detectors for enhancing the selectivity needed to detect species in complex matrices including interferences. Emphasis was placed on development of a mathematical simulation approach to evaluation of coupled detector performance.

This project had several specific goals and objectives. The principal objectives of the project were to develop appropriate mathematical simulation models, to perform initial experimental testing of the models, and to initiate work toward applications. The great majority of the objectives was accomplished. The greatest progress has been made toward the first objective. Initial experimental testing was initiated toward the second objective. Work continues toward implementation of the third objective.

Methodology:

Simulations were carried out using the backward implicit finite difference method to solve the differential equations for convective diffusion in a thin-layer channel. The validity of the simulations was tested for two cases of arrays of microelectrodes, with good agreement being achieved between theory and experiment. The simulations were then extended to treat the spectrophotometric response for generation of absorbing species in the channel as a result of an electrochemical reaction. Provision was made for treatment of shot-limited spectrphotometric noise, so that signal / noise ratios and detection limits could be evaluated. Initial experiments were carried out to evaluate the theoretical treatment.

Principal Findings and Significance:

This report describes in detail the development of the mathematical simulation model, and also describes the initial experimental results. The report is segmented into three chapters, covering three distinct aspects of the project. The material described in the first two chapters has already been submitted for publication in the journal, Analytical Chemistry. The first paper is in press, and the second paper has been preliminarily accepted pending minor revisions, which are included in this report. The third paper is in preparation for submission to a journal.

At the time that this project was initiated, a general approach had been developed for theoretical calculation of concentration profiles in a thin-layer electrochemical detector cell of the type considered in this project. However, there were no experimental data to confirm the validity of the model and its appropriateness for extension to the spectroelectrochemical investigations of this project. Consequently, the first two chapters deal with further development of the generalized simulation model, and experimental evaluation for arrays of electrodes. Success of the model in treatment of arrays of electrodes of varying geometries and spacings greatly enhances confidence in the validity of the model for spectroelectrochemical studies. As seen in these two chapters, the model for current as a function of all investigated parameters is in excellent agreement with theory under a wide variety of conditions, thus ensuring the validity of the simulation approach.

The third chapter extends the approach of the first two chapters to the spectroelectrochemical correlation detector. The predicted response of the detector has been evaluated under a wide range of conditions. The detection limits that can be expected have been investigated on the basis of the simulation model, together with a model of likely spectrophotometric noise sources as a function of experimental conditions. Initial experimental results are in qualitative agreement with the theory, although additional experimental work is still needed.

In summary, the expected response of spectroelectrochemical correlation detectors has been surveyed, and detector design and operating parameters have been evaluated for development of optimum response and performance. It is anticipated that spectroelectrochemical correlation detectors of optimized design will be of significant utility in improvement of the selectivity of environmental analytical measurements.

Publications:

1. Fosdick, L. E., Anderson, J. L., Baginski, T. A., and Jaeger, R. C., "Amperometric Response of Microlithographically Fabricated Microelectrode Array Flow Sensors in a Thin-Layer Channel", submitted to Anal. Chem., 1986.

2. Fosdick, L. E., and Anderson, J. L., "Optimization of Microelectrode Array Geometry in a Rectangular Flow Channel Detector", Anal. Chem., in press, 1986.

3. Fosdick, L. E., and Anderson, J. L., "Spectroelectrochemical Correlation Flow Detector for Enhanced Selectivity", in preparation, 1986.

Professional Presentations:

1. Anderson, J. L., "Optimization of Microelectrode Array Geometry in a Rectangular Flow Channel Detector", Office of Naval Research/National Science Foundation Ultramicroelectrode Workshop, Salt Lake City, Utah, January 24 - 27, 1986.

2. Anderson, J. L., and Fosdick, L. E., "Spectroelectrochemical Correlation Flow Detector for Enhanced Selectivity", Pittsburgh Conference on Analytical Chemistry, Atlantic City, N. J., March 11, 1986.

3. Fosdick, L. E., and Anderson, J. L., "Microelectrode Array Flow Sensors in a Thin-Layer Channel", Auburn University, Auburn, Alabama, June 16, 1986.

M. S. Thesis: None

Ph. D. Thesis: None

SYNOPSIS

Project No : 03

Start : 06/85
End : 06/86

Title : Instantaneous Unit Hydrographs: A Geomorphologic Approach

Investigator : Georgakakos, A.P., School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia

COWRR : 06A

Congressional District : Fifth Georgia

Descriptors : Instantaneous Unit Hydrographs, Markov Process, Reservoir Design, Flood and Drought management

Problem and research objectives :

The need for streamflow generation and forecasting commonly arises in relation with two hydrologic applications: (1) Reservoir design and (2) day-to-day streamflow management for water supply, flood and drought control, and other water uses. Broadly classified, streamflow models may be statistical or physically based. Statistical models are developed fairly easily based on input-output data records; however, they perform poorly for conditions dissimilar to those of their calibration such as the extreme events of floods or droughts. Physically based models simulate the dynamics of the rainfall-runoff process and are more reliable albeit considerably more complex.

The objective of this research initiative is to develop and implement an easy-to-use physically based streamflow model whose parameters can be calibrated from readily measurable geomorphologic and climatic watershed characteristics.

Methodology :

The watershed response is modelled as a Continuous-Time Markov process whose states include both surface and subsurface runoff components. Based on probabilistic arguments, time varying Instantaneous Unit Hydrographs are derived and convoluted with antecedent rainfall intensities to generate streamflow discharges. The method is tested on an actual case study.

Principal Findings and Significance :

The researched approach is the first one to develop Instantaneous Unit Hydrographs accounting for both surface and groundwater runoff. A first case study produced encouraging results and demonstrated the method's potential. More case studies are needed to convert this into a generally applicable model. Such models may be used for quantifying the response of ungaged watersheds and predicting streamflows in real time. In turn, such studies are instrumental in the design and operation of reservoirs.

Publications and professional presentations :

1. Georgakakos, A.P. and Kabouris, J., "Geomorphologic Instantaneous Unit Hydrographs," Journal of Hydrology, 1986 (to be submitted for publication).

2. Georgakakos, A.P. and Kabouris, J., "Instantaneous Unit Hydrographs: A Geomorphologic Approach," Technical Completion Report, Environmental Resources Center, ERC-03-86, Department of the Interior, US Geological Survey, 1986.

3. Georgakakos, A.P. and Kabouris, J., "Instantaneous Unit Hydrographs: A Geomorphologic Approach," American Geophysical Union Meeting, San Francisco, California, Dec. 1986 (to be presented).

M.S. Thesis : None

Ph.D. Dissertation : None

SYNOPSIS

Project No : 04

Start : 06/85
End : 06/86

Title : Cadmium Recovery from Wastes by Cementation onto Magnesium

Investigator : J. P. Gould, H. F. Wiedeman and B. M. Khudenko

COWRR :

Congressional District : Fifth Georgia

Descriptors : Cadmium, Hazardous Wastes, Cementation, Magnesium, Resource Recovery

Problem and research objectives :

Cadmium is a toxic metal whose disposal presents severe problems environmentally. It is also a metal of some value whose recovery would present significant advantages. The objective of this research was to examine the use of cementation (displacement of a metal from aqueous solution by a more electrochemically active metal) to remove cadmium from water as pure elemental cadmium in which form it might easily be recovered and recycled.

Magnesium, a non-toxic element was selected as the sacrificial metal. It is very high on the electrochemical series and, being non-toxic, is an excellent choice to replace a toxic metal.

The primary objective of this study therefore was to investigate the kinetics, efficiency and economics of magnesium cementation of cadmium over a range of pH and cadmium concentration values.

Methodology :

The kinetics of cementation of cadmium by magnesium were studied in a completely mixed batch reactor at room temperature and constant mixing rate and ionic strength. Magnesium strips provided in stoichiometric excess were used as electrodes. The effect of pH and initial cadmium concentration on the rate of cadmium removal and reaction stoichiometry, or moles of magnesium consumed per mole of cadmium cemented, were evaluated.

Principal findings and significance :

The rate of cadmium removal was shown to be independent of pH between 3 and 6. However, as pH increased, the process yield became more favorable. This was attributed to the competing reaction of magnesium dissolution which decreases with increasing pH.

The rate of cadmium removal was studied at initial cadmium concentrations between 1 and 100 mM. It was found that the rate and stoichiometry were highly dependent upon initial cadmium concentration.

At initial concentrations of up to approximately 25 mM, the reaction was found to follow apparent half order kinetics consistent with a migration

control mechanism. As initial cadmium concentrations increased through this range, removal rates also increased. At approximately 25 mM, a transition was observed to apparent first order kinetics consistent with a diffusion control mechanism. There was a significant decrease in removal rates as the initial cadmium concentration increased to levels of greater than 25 mM.

Stoichiometry was found to become more favorable as initial cadmium concentration increased, and in some cases, less than 1 mole of magnesium was required to cement 1 mole of cadmium. This effect was attributed to electrolysis of water by the induced electrochemical system

Publications and professional presentations :

1. Magnesium Cementation of Cadmium. Gould, J. P. and Wiedeman, H. F. To be presented at the International Symposium on Metal Speciation Removal and Recovery, Chicago, IL, July, 1986.

M.S. Thesis : Mr. H. F. Wiedeman

Ph.D. dissertation : None

SYNOPSIS

Project No: 05 Start: 06/85
End: 06/86

Title: A Statistical Analysis of Several Facets of Low Stream Flow Distributions

Investigator: McCormick, W. P., Statistics Department, University of Georgia
Reeves, J. H., Statistics Department, University of Georgia

COWRR: 2E Congressional District: 10th Georgia

Descriptors: Design Low-Flow, Daily Stream Flow Model, Extreme Value Theory

Problem and Research Objectives:

In this report we analyse three problems related to a design low-flow characteristic called 7Q10. The value 7Q10 denotes the tenth percentile of the distribution of the quantity, which gives for a one year period the lowest level of stream flow for which there was a 7 consecutive day period with flows below that value on each day.

The first problem we address is determining monthly 7Q10 values. The 7Q10 value is a very important low-flow characteristic of a stream for the reason that pollution discharge permits are based on that value. A method of assigning 7Q10 values which can vary over the year is of interest in order to allow greater use of the stream for carrying off pollution. We offer a simple method for calculating monthly 7Q10 values, which does not lead to any greater number of daily contraventions below the critical flows than that which already occurs for the one fixed annual 7Q10 method.

The second problem addressed concerns the estimation of 7Q10 with a confidence interval. We offer a method based on a model for daily stream flows and we compare our estimation procedure with two other often used procedures.

The third problem concerns the estimation of 7Q10 when the record of stream flow is only partial and short. We recommend a procedure which incorporates the use of rainfall data into our estimation procedure for 7Q10.

Methodology:

The solution to problem one is straightforward. In order to satisfy the constraint of equal contraventions for the variable 7Q10 and fixed 7Q10 methods, one determines directly from the stream flow record the needed level for each month which achieves this objective.

The solution to problem two is in two parts. The first part relates to the estimation of 7Q10 with a confidence interval under the assumption that the stream flow follows a nonstationary autoregressive normal process. Parameters are introduced to account for fixed difference in the flow over different months and also to account for random differences over different years. All

the model parameters are estimated by standard regression or time series methods. With the model parameters estimated, a boostrapping procedure is then employed to obtain the 7Q10 estimate. By repeating this procedure with the model parameter estimates set at the extremes of their confidence interval, one obtains the limits of the confidence interval for 7Q10.

The second part of the solution to this problem relates to obtaining an asymptotic expression for the sampling distribution of $\min_{1\le i\le n-\ell} \max_{i\le j\le i+\ell} X_j$, the statistic on which 7Q10 is based. A general solution to this problem is presented in the case of stationary flows. While the methodology employed is broadly described as extreme value theory for stationary processes, the techniques developed to obtain asymptotic results for intermediate order statistics based on stationary sequences was particularly relevant to the solution of the general problem.

In the third problem we suggest that rainfall data be used to improve the accuracy of the parameter estimates of the daily stream flow model. Once these parameters have been estimated we suggest implementing our procedure to obtain a confidence interval for 7Q10. Regression is used as the method for incorporating the record of average annual rainfall into our model estimates.

Principal Findings and Significance:

For the first problem an alternative method of obtaining variable 7Q10 values is to separately apply the strict definition of 7Q10 restricted to the stream flow record for each particular month across the several years of data. While this method truly sets a monthly 7Q10 in that definitions are adhered to, it does not maintain the same percentage of contraventions as the fixed annual 7Q10 method. Our computations showed in fact that for the majority of rivers studied, the percentage of days that fell below these monthly 7Q10 values was 3 to 6 times greater than for the traditional method. Depending on the implications to the aquatic ecosystem of the stream receiving more pollution on a given day than the flow can handle, one can judge the need to use the lower 7Q10 values given by our method which will not increase the percentage of days contravened.

With regard to the second problem, we found that our method yielded much sharper error bounds than the very conservative nonparametric method or a method based on a log-normal distribution for 7Q10 values. This is expected since greater use of the available data is made using our method. However, care should be taken to see that our model provides a reasonable fit to the stream flow data before application of our method. With regard to the asymptotic distribution of $\min_{1\le i\le n-\ell} \max_{i\le j\le i+\ell} X_j$, the analysis of that section (appendix 1) provides the formula for calculating the limiting distribution. In the case of a stationary Gaussian sequence, the normalizing coefficients are calculated from the covariance matrix of the joint distribution of stream flow over ℓ consecutive days. A notable feature of our results is that the mixing conditions, under which our theorems hold are expressed in terms of the correlation function. A decay of the of the form m^{-a} suffices for our results so that autoregressive models fall

within the domain of applicability.

With regard to the third problem we offer it as a method to extend our procedure based on a full record of daily stream flows to a situation where only a partial record exists. The success of this approach depends on the degree to which average annual rain fall is correlated with one of the effects in our model.

Publications and Professional Presentations:

1. McCormick, W.P. and Reeves, J.H., "Weak Convergence Result for the Maxima of Consecutive Minima for Stationary Processes", submitted to Stochastic Models.

2. McCormick, W.P. and Reeves, J.H., "An Estimation Procedure for a Design Low-Flow Based on a Daily Stream Flow Model", (In preparation.)

3. McCormick, W.P., "Weak and Strong Law Results for the Maxima of Consecutive Minia", Institute of Mathematical Statistics, Academia Sinica, Annual Meeting, Taiwan, 1985.

M.S. Thesis: None

Ph.D. Dissertation: None

SYNOPSIS

Project No : 06

Start : 06/85
End : 06/86

Title : Evaluation of User Charges to Finance Water Projects

Investigators : Ronald M. North, Jackie Sellers and J. Owens Smith with graduate students Hubert A. Pless and Yoko Parmelee, Institute of Natural Resources, The University of Georgia, Athens, Ga. 30602

COWWR : 06C

Congressional District : Tenth, Georgia

Descriptors : Financing, Pricing, User Charges, Cost Sharing, Financial Feasibility, Economic Cost, Water Rates, Repayment, Demand, Benefit Cost Analysis, Cost Allocation, Water Rights, Tariff, Market Value, Water Policy

Problem and research objectives :

Georgia, and other states, are faced with rapidly declining Federal investments (loans, grants, direct construction) from all Federal Agencies (USDA/SCS/FmHA; Commerce/EDA, COE, EPA, et. al.). Georgia, in its 1984 legislation, created the community facilities program in the Georgia Development Authority for the purpose of generating capital funds for water and sewerage facilities. There remains the critical issue of how to amortize these loans as well as local investments through effective user charges. The problems addressed in this research are those of rate structures, cost based prices, market value process, flat rates, block rates, assessments, etc. Consideration must be given to cost allocation (who pays) and to financial burdens such as those included in subsidies, etc. The final need is for an effective mechanism to develop and maintain the water services infrastructure to meet current and projected needs as well as economic development goals of Georgia, other states and communities.

The objective of this research is to evaluate existing user charges for major water outputs -- domestic supply and power to suggest innovative pricing arrangements that might support water resources financing needs. The expected result will be critically evaluated sets of pricing options that could be used effectively by Federal, state/local governments and the private sector in structuring an improved water resources financing system. Three options will include, in all cases, the associated fees, user charges, prices and other means of liquidating project costs in a manner that is equitable to all classes of users both presently and over time.

Methodology :

The method is descriptive in the first stage and quantitative in the second stage. (1) Identify and describe existing funding and repayment mechanisms; (2) Identify and describe financing and repayment mechanisms utilized in selected cases for selected water outputs; (3) Propose new

mechanisms and pricing structures that promote conservation and generate required revenues, for example -- time of use charges, demand charges, block rate charges, assessments and others. This research was conducted in two stages -- (1) the identification and description of the available pricing mechanisms and (2) the evaluation of each pricing system (average cost, marginal cost, block rates, time of use, etc.) for efficiency, equity and practicality. Substantial data are available on historical costs of projects, repayments to sponsoring agencies and applications of funds. These data are on line to be analyzed by economic and financial criteria common to normal business practices.

Principal findings and significance :

The researchers review demand theory and present a case study for price/income elasticities of demand for Georgia municipal systems to illustrate price and income effects on revenues. Similar theoretical constructs are presented for two market pricing solutions and for discriminatory pricing within a market for flow type commodities, both systems intended to generate revenue more closely aligned to market value of the services provided. A second case study is used to show how updated "alternative cost" pricing will lead to increases of 4-10 times in the revenue received from hydropower generation (capacity and energy). Although some repayments are long term contracts, there are opportunities to renegotiate contracts for better terms to Federal agencies producing and marketing hydropower. Specific details are given for the Southeastern Power Administration (SEPA).

Publications and professional presentations :

1. Ronald M. North, Yoko Parmelee, J. Owens Smith and Jackie Sellers, "Financing Wetlands Acquisition and Management", Symposium on Freshwater Wetlands and Wildlife, Savannah River Ecology Laboratory, Charleston, SC, March 25, 1986.

2. Ronald M. North, "Financial Capabilities and Arrangements of Local Governments to Protect Groundwater", Symposium on Groundwater Policy, National Water Alliance, Colorado Springs, Co., April 17, 1986.

3. Ronald M. North, "Institutional Mechanisms for User Charges in Financing Environmental Aspects of Development", Conferencia Sobre La Economia del Medio Ambiente", Universidad Autonóma de Nuevo León, Monterrey, Mex., September 25, 1985.

4. Ronald M. North, "Institutional Mechanisms for User Charges in Financing Water Resources", Engineering Foundation Conference on Water Resources Planning and Management in the Federal System", Henniker, NH, July 9, 1986.

M. S. Thesis : Hubert Allison Pless, An Economic Analysis of Residential Electricity Demand in Rural Georgia, Master of Science Thesis, The University of Georgia, Athens, Ga., January 1, 1985.

Ph.D. dissertation : None

SYNOPSIS

Project No.: 07 Start: 06/85
End: 06/86

Title: Alluvial Streambed Degradation

Investigator: Sturm, Terry W., School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia

COWRR: 2J Congressional District: 5th, Georgia

Descriptors: Bed Load, Dams, Rivers, Sediment

Problem and Research Objective:

The erosion of streambanks and streambeds has become an important national problem. The types of damage that are occurring include streambank erosion, sloughing, bed degradation, and head-cutting, which combine to produce serious economic losses. These damages are often the result of man's activities, and their occurrence is often unforeseen due to the complexity of the physical process of sediment transport in rivers.

The purpose of this research project was to investigate one special case of man's effect on rivers: the streambed adjustments which occur downstream of dams on alluvial rivers. Previous experimental laboratory research and field data indicate that these adjustments can include both scour and fill in the same cross section, i.e. changes in bed elevation occur in both the transverse and longitudinal directions with respect to the flow direction. Previous numerical and analytical models have considered only some mean bed elevation change across the whole river cross section. The specific objective of this research was to develop a numerical model of the two-dimensional streambed adjustments downstream of a dam in a relatively straight reach of a wide, alluvial river.

Methodology

As a guide to numerical model development, and for model calibration and verification, experimental results were obtained from a physical laboratory model of an existing alluvial river. The diversion discharge structure was operated at a flow rate of 1.2 cfs for a total of 16 hours, and bed elevation data in the downstream river bed were collected at several intermediate time steps as well as at the beginning and end of the complete test. Transverse velocity profiles and water surface profiles were also measured.

In the development of the numerical model, the problem is approached as a quasi-steady, gradually-varied flow with nonequilibrium bed load transport. The water flow rate is held constant in the model, but the bed elevations, water surface elevations, and transverse velocity distributions are allowed to

vary with time. The sediment continuity equation is solved numerically in each of several streamtubes at each cross section. The boundary condition consists of specified sediment supply rates from local scour hole development at the upstream end of the river reach. After the sediment bed adjustments are made, the water surface profile and the streamtube divisions are recomputed at each time step. The result is a time record of the development of changes in the cross sectional shape, although channel widening is not included in the present version of the numerical model.

Principal Findings and Significance

The experimental results demonstrated the link between the hydraulic behavior of the outlet structure and the development of the channel bed adjustments at the upstream end of the river reach. An alluvial point bar moved through the river reach causing fill on one side of the cross sections and scour on the other side due to a channel choking effect. Mean bed elevations at each cross section were shown to mask the complexity of the fill and scour processes occurring at each cross section. The data further demonstrated that an equilibrium sediment transport relation could be used downstream of the local scour area even though the bed was not in equilibrium.

The numerical model successfully predicted trends of scour and fill in the same cross section, but the magnitudes were too small because the effect of channel widening at the upstream end of the river reach was not accounted for. The central difference approximation in an explicit finite difference model of the sediment continuity equation was found to be stable, but a backward difference scheme was unstable. The sensitivity of the numerical model to the upstream boundary condition, the sediment porosity, the sediment transport relation, and the time step was explored. The streamtube approach was found to be a viable technique for investigating two-dimensional streambed adjustments, but additional refinements related to the fundamental problems of transverse velocity distribution and streambank failure are needed as these problems are illuminated by further research.

Publications and Professional Presentations

Sturm, T.W., and Skolds, D.M., "Alluvial Streambed Degradation," Technical Completion Report ERC01-86, Environmental Resources Center, Georgia Institute of Technology, Atlanta, GA, July,1986.

Skolds, D.M., and Sturm, T.W., "Alluvial Stream Bed Adjustments in a Laboratory Model," Proceedings of the Third International Symposium on River Sedimentation, ed. by S.Y. Wang, H.W. Shen, and L.Z. Ding, University, Mississippi, April, 1986, pp.235-244.

Sturm, T.W., Skolds, D.M., and Blalock, M.E., "Water Surface Profiles in Compound Channels," Proceedings Hydraulics Specialty Conference, ASCE, Hydraulics and Hydrology in the Small Computer Age, Vol. 1, Lake Buena Vista, Fla., Aug. 1985, pp. 569-574.

M.S. Thesis

Skolds, D.M., "Alluvial Stream Bed Adjustments Downstream of Hydraulic Structures," Thesis Presented in Partial Requirements for the M.S. Degree in Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia, 1985.

Thein, M., "Alluvial Channel Widening Due to Bank Failure," M.S. Thesis in Progress, 1986.

INFORMATION TRANSFER ACTIVITIES

The Environmental Resources Center gives wide distribution to the products of its research program and those from the Water Resources Research Institutes in other states. Research projects completed as part of its program are published in its report series for scientific and technical use. A complete publications list for work beginning in 1964 is given in Table 3. The six projects completed as part of this annual program are listed as numbers ERC 01-86 to 06-86. Reports provided by other Institutes are on file at the Georgia Institute of Technology Library and are available for borrowing or copying.

Considerable efforts are devoted assuring that the research projects include useful information transfer components. The potential for information transfer is a selection criterion for the project; the technical completion report is reviewed for its capacity for advancing knowledge of the field; and the principal investigators are encouraged to submit papers and give presentations based on their work.

Reports listed with P.B. numbers may be purchased from the NTIS, U.S. Department of Commerce, Springfield, Virginia 22161, at the indicated price. Reproductions of these reports may also be purchased from the Georgia Tech Information Exchange Center at the Price Gilbert Library for 1) $0.20 per page plus a $3.00 handling charge for southeastern academic institutions or 2) $0.20 per page plus a $4.00 handling charge for academic institutions outside the southeast and all others. Those who want multiple copies of a report or who need a report after the Center's supply has been exhausted can be accommodated by one of these two methods.

The Environmental Resources Center maintains three mailing lists as part of its information dissemination program. The first is for those who request copies of all future ERC reports. The second is for those who wish to receive abstracts of all new ERC reports as they are published so that they can use the abstracts to request reports of particular interest. The third is for those individuals who wish to obtain a list of water resources research reports received by ERC from water resources research institutes in the other states and from non-USDI research groups. The reports are deposited every few months in the Georgia Tech Library, and deposited items are recorded. Recipients of this record can then borrow or purchase copies from the Information Exchange Center at the Library.

The periodic meetings by the directors of water resources research institutes in the South Atlantic-Gulf region continue to provide interchange of information concerning research of mutual interest in view of the commonality of physiographic regions with associated needs and problems. The meetings of the National Association of Water Institute Directors provides a forum for information exchange on a national basis.

Table 5
List of Publications
Environmental Resources Center

WRC Number	Title	Out-of-Stock Information
0166	The State of the Art of Water Use and Waste Disposal in the Textile Industry (1950-66), by Leonard D. Jones and William L. Hyden, June 1966, 27 pp.	---
0266	The Effect of a Permeable Bed on Sediment Motion--Phase I: Seepage Force on Bed Particles, By C.S. Martin, June 1966, 60 pp. (B-004-GA).	---
0366	Survey of the Nature and Magnitude of the Water Research Needs of the Textile Industry of Georgia, by William L. Hyden, Douglas F. Becknell, and Telford E. Elders, June 1966, 27 pp. (A-010-GA).	---
0466	Seepage Flow Through an Earth Dam, by M.R. Carstens and George D. May, July 1966, 68 pp.	---
0566	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1966, Water Resources Center, August 1966, 60 pp.	---
0167.5	(Reprint) Selected Chapters from Organization and Methodology for River Basin Planning, by C.E. Kindsvater, ed., 132 pp.	---
0267.5	(Reprint) Pilot Studies on the Anaerobic Treatment of Tannery Effluents, by W.E. Gates and Sun-Dar Lin, 20 pp.	---
0367.5	(Reprint) A Fresh-Water Canal as a Barrier to Salt-Water Intrusion, by S. Charmonman, M.R. Carstens, and G.D. May, 7 pp.	---
0467.5	(Reprint) Evolution of a Duned Bed Under Oscillatory Flow, by M.R. Carstens and F.M. Neilson, 7 pp.	---
0567	Salt-Water Intrusion Effect of a Fresh-Water Canal, by M.R. Carstens and George D. May, May 1967, 41 pp. (B-003-GA).	---
0667	Georgia Laws, Policies and Programs Pertaining to Water and Related Land Resources, by George R. Elmore, Jr., June 1967, 112 pp.	---
0767	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1967, Water Resources Center, August 1967, 116 pp.	---

WRC Number	Title	Out-of-Stock Information
0867	The Movement of Micron-Size Particles Through a Sand Bed, by Jerry B.F. Champlin, December 1967, 106 pp.	---
0967	Diffusion of Particles by Turbulence: Effect of Particle Size, by Hirendra Majumdar and M.R. Carstens, December 1967, 102 pp.	---
0168	Hydraulic Investigations of Tainter Gates as Flow Measuring Devices, by Paul G. Mayer and Bruce R. Olmstead, April 1968, 103 pp.	---
0268	Metropolitan Planning and River Basin Planning: Some Interrelationships, by Guy J. Kelnhofer, Jr., July 1968, 218 pp. (B-009-GA).	---
0368	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1968, Water Resources Center, August 1968, 101 pp.	---
0468	The Effect of Induced Turbulence on the Growth of Algae, by Lawrence W. Olinger, September 1968, 81 pp.	---
0568	The Effect of Turbulence on Bacterial Substrate Utilization, by John T. Marlar, December 1968, 110 pp.	---
0668	Development and Application of a Rational Water Quality Planning Model, by Benjamin C. Dysart, III, and William W. Hines, January 1969, 182 pp. (A-012-GA).	---
0868	Determination, Evaluation and Abatement of Color in Textile Plant Effluents, by R.K. Flege, December 1968, 59 pp. (B-012-GA).	---
0169	(Reprint) Potassium, Illite and the Ocean, by Charles E. Weaver, 16 pp.	---
0269	A Stochastic Model for the Response of Permanent Offshore Structures Subject to Soil Restraints and Wave Forces, by Billy L. Edge and Paul G. Mayer, April 1969, 203 pp.	P.B. No. 232-178 Paper copy, $7.25 Microfiche, $2.25
0369	The Relation of Ion Movement to Fine Particle Displacement in a Sand Bed, by Jerry B.F. Champlin, July 1969, 22 pp. (A-002-GA).	P.B. No. 187-521 Paper copy, $3.25 Microfiche, $2.25
0469	Radiotracer Study of Rapid Sand Filtration, by Thomas Fisher Craft, Jr., August 1969, 179 pp. (B-020-GA).	P.B. No. 187-522 Paper copy, $7.00 Microfiche, $2.25
0569	Instruments for Measuring Attitude Toward a Community Water Issue, by C. Michael York, September 1969, 35 pp. (B-024-GA).	P.B. No. 188-502 Paper copy, $3.75 Microfiche, $2.25

WRC Number	Title	Out-of-Stock Information
0669	A Study of Flow Conditions in Shaft Spillways, by Yusuf G. Mussalli and M.R. Carstens, September 1969, 158 pp. (B-022-GA).	P.B. No. 188-909 Paper copy, $6.25 Microfiche, $2.25
0769	Changes in Clay-Water System with Depth, Temperature and Time, by Charles E. Weaver and Kevin C. Beck, October 1969, 95 pp. (A-008-GA).	P.B. No. 189-168 Paper copy, $4.75 Microfiche, $2.25
0869	The Effect of a Permeable Sand Bed on Sediment Motion, by C. Samuel Martin and Mustafa N. Aral, November 1969, 97 pp. (B-019-GA).	P.B. No. 189-404 Paper copy, $4.75 Microfiche, $2.25
0969	Kinetics of Aerobic Utilization of Mixed Sugars by Heterogeneous Microbial Populations, by Sambhunath Ghosh, November 1969, 467 pp.	P.B. No. 230-797 Paper copy, $11.50 Microfiche, $2.25
1069	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1969, Water Resources Center, November 1969, 93 pp.	---
1169	The Transport of Radioisotopes by Fine Particulate Matter in Aquifers, by Jerry B. Francis Champlin, December 1969, 187 pp.	P.B. No. 232-179 Paper copy, $7.00 Microfiche, $2.25
0170	Unsteady Flow of Dilute Aqueous Polymer Solutions in Pipe Networks--A Method to Improve Water Distribution, by Henry C. Jackson and Paul G. Mayer, January 1970, 134 pp. (A-016-GA).	P.B. No. 190-488 Paper copy, $5.75 Microfiche, $2.25
ERC Number		
0270	Determination of Degraded Dyes and Auxiliary Chemicals in Effluents from Textile Dyeing Processes, by R.K. Flege, March 1970, 42 pp. (B-027-GA).	P.B. No. 191-708 Paper copy, $3.75 Microfiche, $2.25
0370	The Numerical Solution of Transient Supercritical Flow by the Method of Characteristics with a Technique for Simulating Bore Propagation, by Jerome J. Zovne, May 1970, 165 pp.	P.B. No. 232-143 Paper copy, $6.25 Microfiche, $2.25
0470	The Application of Phase Selective Alternating Current Polarography to the Analysis of Heavy Metals in Water, by Peter E. Sturrock and Robert L. Poole, Jr., June 1970, 55 pp. (A-020-GA).	P.B. No. 193-412 Paper copy, $4.25 Microfiche, $2.25
0570	Complex Systems Analysis of Water Quality Dynamics: The Feedback Systems Structure, by John E. Knight and William W. Hines, September 1970, 88 pp. (A-023-GA).	P.B. No. 196-901 Paper copy, $4.75 Microfiche, $2.25

ERC Number	Title	Out-of-Stock Information
0670	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1970, Water Resources Center, September 1970, 89 pp.	---
0770	Removal of a Spherical Particle from a Flat Bed, by Charng N. Chen, November 1970, 96 pp.	P.B. No. 232-174 Paper copy, $4.75 Microfiche, $2.25
0171	Laboratory and Mathematical Simulation of Oxygen Balances Effected in Streams, by William E. Gates, April 1971, 52 pp. (A-003-GA).	P.B. No. 200-821 Paper copy, $4.25 Microfiche, $2.25
0271	A Citizen Panel for Atlanta Area Studies: Field Experimentations and Methodological Substudies, by C. Michael York and Glen D. Baskett, June 1971, 64 pp. (B-045-GA).	P.B. No. 202-984 Paper copy, $4.25 Microfiche, $2.25
0471	Turbidity Instrumentation: A Fiber-Optic System for Measuring Sediment Concentration by Optical Fourier Transformation, by Albert McSweeney, July 1971, 22 pp. (A-027-GA).	P.B. No. 202-985 Paper copy, $3.25 Microfiche, $2.25
0571	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1971, Water Resources Center, September 1971, 82 pp.	---
0671	The Flood Plain as a Residential Choice: Resident Attitudes and Perceptions and Their Implications to Flood Plain Management Policy, by L. Douglas James, Eugene A. Laurent, and Duane W. Hill, October 1971, 288 pp. (C-1786).	P.B. No. 206-424 Paper copy, $8.75 Microfiche, $2.25
0771	Remedial Flood Plain Management as the Focus for an Experiment in Interdisciplinary Team Research, by L. Douglas James, October 1971, 76 pp. (C-1786).	P.B. No. 206-425 Paper copy, $4.75 Microfiche, $2.25
0871	The Effects of Land Use Change on the Hydrology of an Urban Watershed, by James R. Wallace, October 1971, 66 pp. (C-1786).	P.B. No. 206-426 Paper copy, $4.25 Microfiche, $2.25
0971	The Peachtree Creek Watershed as a Case History in Urban Flood Plain Development, by L. Douglas James, Guy J. Kelnhofer, G. Roy Elmore, and Eugene A. Laurent, October 1971, 83 pp. (C-1786).	P.B. No. 206-427 Paper copy, $4.75 Microfiche, $2.25
1071	A Study of Public Attitudes and Multiple Objective Decision Criteria for Water Pollution Control Projects, by Gerald J. Thuesen, October 1971, 70 pp. (A-028-GA).	P.B. No. 205-181 Paper copy, $4.25 Microfiche, $2.25
0172	Transition Metals Impounded in Waters, by John J. Heise, June 1972, 46 pp. (B-023-GA).	P.B. No. 213-160 Paper copy, $3.75 Microfiche, $2.25

ERC Number	Title	Out-of-Stock Information
0272	Some Important Inorganic Nitrogen and Phosphorus Species in Georgia Salt Marsh, by Peter Robert Maye, III, May 1972, 60 pp. (B-033-GA).	P.B. No. 210-713 Paper copy, $4.25 Microfiche, $2.25
0372	Chemical Characterization of Dissolved Organic Matter and Its Influence on the Chemistry of River Water, by J. Helmut Reuter and Edward M. Perdue, May 1972, 33 pp. (A-026-GA).	P.B. No. 210-714 Paper copy, $3.75 Microfiche, $2.25
0472	State Organization for Water Resources Management, by George Roy Elmore, Jr., May, 1972, 143 pp.	P.B. No. 232-142 Paper copy, $5.75 Microfiche, $2.25
0572	The Structure and Properties of Water Solutions, by Robert A. Pierotti and Albert A. Liabastre, June 1972, 102 pp. (A-017-GA).	P.B. No. 211-163 Paper copy, $5.75 Microfiche, $2.25
0672	The Role of Sediment Gradation on Channel Armoring, by William C. Little and Paul G. Mayer, May 1972, 104 pp.	P.B. No. 232-164 Paper copy, $5.25 Microfiche, $2.25
0772	A Program for Metropolitan Water Management, by Gene E. Willeke and F. William Kroeck, July 1972, 214 pp. (B-038-GA).	P.B. No. 212-717 Paper copy, $7.25 Microfiche, $2.25
0872	Sediment Water Interactions in Some Georgia Rivers and Estuaries, by Kevin C. Beck, July 1972, 97 pp. (B-033-GA).	P.B No. 211-611 Paper copy, $4.75 Microfiche, $2.25
0972	Digital Simulation of Thunderstorm Rainfall, by Unal A. Sormon and James R. Wallace, August 1972, 177 pp. (A-036-GA).	P.B. No. 211-806 Paper copy, $7.00 Microfiche, $2.25
1072	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1972, Water Resources Center, July 1972, 69 pp.	---
1172	A Study of the Effects of Island Development on Lake Water Quality, by Mark A. McClanahan and Alfred W. Hoadley, September 1972, 49 pp. (A-034-GA).	P.B. No. 213-161 Paper copy, $3.75 Microfiche, $2.25
0173	An Examination of the Economic Impact of Pollution Control Upon Georgia's Water-Using Industries, by Winfred G. Dodson and Robert B. Cassell, February 1973, 43 pp. (B-064-GA).	P.B. No. 220-006 Paper copy, $3.75 Microfiche, $2.25
0273	Volume Transport, Salinity Distribution and Net Circulation in the Duplin Estuary, Georgia, by Bjorn Kjerve, April 1973, 30 pp. (B-035-GA).	P.B. No. 221-535 Paper copy, $3.75 Microfiche, $2.25

ERC Number	Title	Out-of-Stock Information
0373	Physical and Chemical Properties of the Coastal Waters of Georgia, by R. Kuroda and F.C. Marland, April 1973, 82 pp. (B-035-GA).	P.B. No. 220-680 Paper copy, $4.75 Microfiche, $2.25
0473	Studies of Saprolite and Its Relation to the Migration and Occurrence of Groundwater in Crystalline Rocks, by J. Hatten Howard, III, June 1973, 23 pp. (B-010-GA).	P.B. No. 222-002 Paper copy, $3.25 Microfiche, $2.25
0573	Microbial Changes and Possible Ground Water Pollution from Poultry Manure and Beef Cattle Feedlots in Georgia, by Joel Giddens, A.M. Rao, and Herbert W. Fordham, May 1973, 57 pp. (A-031-GA).	P.B. No. 220-956 Paper copy, $4.25 Microfiche, $2.25
0673	Cost of Waste Water Pollution Abatement in Poultry Processing and Rendering Plants in Georgia, by Waldon R. Kerns and Fred J. Holemo, June 1973, 39 pp. (A-038-GA).	P.B. No. 222-506 Paper copy, $3.75 Microfiche, $2.25
0773	The Identification and Quantification of the Net Effects of Multiple-Purpose River Basin Development, by Ronald M. North and Jackie Sellers, June 1973, 155 pp. (A-040-GA).	P.B. No. 228-588 Paper copy, $6.25 Microfiche, $2.25
0873	The Relationship of Land Use to Domestic Surface Water Supply in Georgia, by D.W. Shaw and W.L. Nutter, June 1973, 53 pp. (A-039-GA).	P.B. No. 236-429 Paper copy, $4.25 Microfiche, $2.25
0973	Parabiotic Growth Characteristics of Selected Sewage Bacteria, by Edward L. Fincher, July 1973, 168 pp. (B-053-GA).	P.B. No. 226-769 Paper copy, $6.25 Microfiche, $2.25
1073	Annual Report, Water Resources Research Activities under Public Law 88-379, Fiscal Year 1973, Water Resources Center, August 1973, 71 pp.	---
1173	Georgia's Water Problems and Related Research Needs, by Gene E. Willeke, Arthur C. Benke, Alan M. Lumb, Billy H. Kornegay, and Walter P. Neely, August 1973, 100 pp. (A-041-GA).	P.B. No. 224-433 Paper copy, $4.75 Microfiche, $2.25
1273	Travel Time of Georgia Streams, by Alan M. Lumb, September 1973, 80 pp. (A-042-GA)	P.B. No. 224-848 Paper copy, $4.75 Microfiche, $2.25
1373	Utilization of Organic Phosphorus by Plankton in Phosphorus-Rich Environments, by John R. Strange, October 1973, 34 pp. (A-035-GA).	P.B. No. 231-304 Paper copy, $3.75 Microfiche, $2.25

ERC Number	Title	Out-of-Stock Information
1473	The Interaction of Water with Organic Solute Species, by Charles L. Liotta, H.P. Hopkins, Jr., and M. Perdue, September 1973, 140 pp. (B-049-GA).	P.B. No. 227-250 Paper copy, $5.75 Microfiche, $2.25
1573	Studies on the Validity of Darcy's Law for Flow in Natural Sands, by Robert G. Carver, November 1973, 44 pp. (A-037-GA).	P.B. No. 228-022 Paper copy, $3.75 Microfiche, $2.25
1673	Effect of Polyester Fiber Processing Effluents on Water Quality, by Wayne C. Tincher, November 1973, 51 pp. (A-043-GA).	P.B. No. 227-383 Paper copy, $4.25 Microfiche, $2.25
0174	Community Well-Being as a Factor in Urban Land Use Planning, by L. Douglas James, Donna R. Brogan, Eugene A. Laurent, and Henri Etta Baltimore, January 1974, 218 pp. (C-2064).	P.B. No. 227-339 Paper copy, $7.25 Microfiche, $2.25
0274	The Use of Questionnaires in Collecting Information for Urban Flood Control Planning, by L. Douglas James, February 1974, 313 pp. (C-2064).	P.B. No. 232-423 Paper copy, $9.25 Microfiche, $2.25
0374	Sensitivity Analysis of a Thunderstorm Rainfall Model, by James R. Wallace and Kwei-Lin L. Wang, January 1974, 73 pp. (A-036-GA).	P.B. No. 230-695 Paper copy, $4.25 Microfiche, $2.25
0474	Buffer Capacity in Aquatic Ecosystems, by Frederick G. Pohland and William R. Bolton, March 1974, 43 pp. (A-033-GA).	P.B. No. 231-469 Paper copy, $3.75 Microfiche, $2.25
0574	Analysis of Urban Land Treatment Measures for Flood Peak Reduction, by Alan M. Lumb, James R. Wallace, and L. Douglas James, June 1974, 146 pp. (C-2064).	P.B. No. 236-418 Paper copy, $5.75 Microfiche, $2.25
0674	The Electrical Process in the Breaking of Dilute Oil-in-Water Emulsions, by Clyde Orr, Jr., and Edward Y.H. Keng, June 1974, 15 pp. (A-049-GA).	P.B. No. 235-908 Paper copy, $3.25 Microfiche, $2.25
0874	The Trace Analysis of Water for Selected Metallic Elements Employing Square-Wave Poloragraphy, by Peter E. Sturrock and Richard Carter, July 1974, 130 pp. (B-063-GA).	P.B. No. 235-406 Paper copy, $5.75 Microfiche, $2.25
0974	Survey of Economic-Ecologic Impacts of Small Watershed Development, by Ronald M. North, A.S. Johnson, H.O. Hillestad, P.A.R. Maxwell, and R.C. Parker, June 1974, 122 pp. (B-059-GA).	P.B. No. 235-407 Paper copy, $5.25 Microfiche, $2.25
1074	Land Disposal of Wastewater: Processes, Design Criteria, and Planning Considerations, by John P. Hartigan, Jr., August 1974, 166 pp.	P.B. No. 235-311 Paper copy, $6.25 Microfiche, $2.25

ERC Number	Title	Out-of-Stock Information
1274	The Effect of Hypolimnion Discharge upon Age and Growth of the Blue Gill (Lepomis Macrochrius), by Richard Dudley and Robert T. Golden, August 1974, 35 pp. (B-057-GA).	P.B. No. 236-589 Paper copy, $3.75 Microfiche, $2.25
1374	Reservoir Project Reauthorization: Examples of Past Use and Analysis of Application to Lake Lanier, by Kenneth R. Holley and Edward P. Kane, August 1974, 161 pp.	P.B. No. 236-408 Paper copy, $6.25 Microfiche, $2.25
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COOPERATIVE ARRANGEMENTS

The Environmental Resources Center is the water resources research institute for Georgia under the Water Resources Research Act of 1984 (PL 98-242). Its water resources research program is managed in accord with guidelines and regulations issued by the U.S. Geological Survey of the Department of the Interior and is operated in part by funds -- $109,000 in FY 1985 -- provided by that agency. These funds are available to all researchers at universities and colleges in Georgia for research in support of water management for the state. The State Board of Regents provided equal matching funds through salaries paid the researchers by universities and colleges.

Center management activities are overseen by The Georgia Water Resources Research Advisory Committee (see Table 4). Research priorities are recommended by the Georgia Water Resources Research Program Development Committee (see Table 5), which met during this period on June 28, 1985. to assure that the research program is responsive to the needs of the state water management agency -- the Georgia Department of Natural Resources (DNR) -- three of the senior officials are members of the research development committee. Furthermore, all research preproposals are evaluated by DNR professional staff, and DNR members are designated as monitors for each selected research project.

The projects that comprise the annual program are selected from preproposals submitted in response to annual requests for proposals issued by the Center together with the list of priority water resources research needs. Each preproposal is evaluated by peer reviewers at universities and colleges and State and Federal water resources agencies on the basis of response to needs and the quality of the submission. The annual program is developed and managed with the participation of the Director, Institute of Natural Resources, University of Georgia, in recognition of the major contributions to the water resources research in the state by the University of Georgia and the Georgia Institute of Technology. Participation by researchers at other schools is encouraged and has been supported.

TRAINING ACCOMPLISHMENTS

Training students so that they may contribute to water resources management is a vital part of the Center program. The training is accomplished by student participation in the sponsored research. In fact, a major portion of current research project funds is devoted to student support, notably for graduate students undertaking thesis research. The training function is summarized in Table 6.

Table 3

GEORGIA WATER RESOURCES RESEARCH ADVISORY COMMITTEE

Function: Advises the Director on Operating Policies and Procedures

Chairman: Bernd Kahn, Director, Environmental Resources Center

University of Georgia

J. L. Kay, Vice President for Research

R. H. Brown, Head, Agricultural Engineering Department
College of Agriculture

R. M. North, Director, Institute of Natural Resources

Alternate

W. L. Nutter, Professor, School of Forest Resources

Georgia Institute of Technology

T. E. Stelson, Vice President for Research

W. M. Sangster, Dean, College of Engineering

J. M. Spurlock, Director, Office of Interdisciplinary Programs

Alternate

J. W. Dees, Director, Office of Contract Administration

Regents, University System of Georgia (Observer)

H. R. Pounds, Vice Chancellor for Research and Planning

Table 5

GEORGIA WATER RESOURCES RESEARCH PROGRAM DEVELOPMENT COMMITTEE

Advises the Director on Water Resources Research Needs in Georgia

Member	Representative
Department of Natural Resources	
Mr. Leonard Ledbetter, Commissioner Department of Natural Resources Floyd Towers East 205 Butler Street, SE Atlanta, GA. 30334 404/656-3500	Mr. Jack Dozier, Chief Water Protection Branch Department of Natural Resources Floyd Towers East, Rm 1058 205 Butler Street, SE Atlanta, GA. 30334 404/656-4708 Mr. William H. McLemore, Chief Georgia Geologic Survey Department of Natural Resources Agriculture Building, Rm 402 19 Martin Luther King Jr. Dr., SW Atlanta, GA. 30334 404/656-3214 Mr. David Word, Chief Water Resources Management Branch Environmental Protection Division Department of Natural Resources Floyd Towers East, Rm 1166 205 Butler Street, SE Atlanta, GA. 30334 404/656-3094
Corps of Engineers, South Atlantic Division	
General Kenneth McIntyre, Div. Engr. South Atlantic Division Corps of Engineers 30 Pryor Street, SW Atlanta, GA 30303 404/526-6711	Mr. John Rushing, Chief Environmental Resources Branch S. Atlantic Div., Corps of Engrs. 30 Pryor Street, SW Atlanta, GA. 30303 404/221-6701
U.S. Environmental Protection Agency	
Mr. Jack Ravan, Regional Admin. Environmental Protection Agency 345 Courtland Street, NE Atlanta, GA. 30365 404/347-4727	Mr. John T. Marlar, Chief Water Quality Management Branch Environmental Protection Agency 345 Courtland Street, NE Atlanta, GA. 30365 404/347-4793
Georgia Conservancy, Inc.	
Ms. Evelyn Hopkins 4424 Jett Rd. NW Atlanta, GA. 30327 404-255-7018	same

Table 5 (cont)

GEORGIA WATER RESOURCES RESEARCH PROGRAM DEVELOPMENT COMMITTEE

Member	Representative
Georgia Institute of Technology	
Dr. Bernd Kahn, Director Environmental Resources Center (0335) Georgia Institute of Technology Atlanta, GA. 30332 404/894-3776	
Georgia Power Company	
Mr. C.R. Thrasher Manager of Engineering Georgia Power Company P.O. Box 4545 Atlanta, GA. 30302 404/526-6526	Mr. Major H. Thompson, Jr. Chief of Civil Engineering Georgia Power Company P.O. Box 4545 Atlanta, GA. 30302 404/526-7140
Georgia Area Planning and Development Commissions	
Mr. Ted Fortino, Executive Director Altamaha Georgia Southern Area Planning and Development Agency P.O. Box 328 Baxley, GA. 31513 912/367-3648	same
U.S. Geological Survey	
Dr. Jeffrey Armbruster, District Chief U.S. Geological Survey 6481 Peachtree Industrial Blvd. Suite B Doraville, GA. 30360 404/221-4858	same
University of Georgia	
Dr. Ronald M. North, Director Institute of Natural Resources University of Georgia Athens, GA 30602 404/542-1555	same
Georgia State Soil and Water Conservation Committee	
Mr. Gary L. Tyre, Executive Director Georgia State Soil and Water Conservation Committee 1867 West Broad Street Athens, GA. 30606 404/542-3065	Mr. Graham Liles Georgia State Soil and Water Conservation Committee 1867 West Broad Street Athens, GA. 30606 404/542-3065

Table 6

Training Accomplishments

Academic Disciplines	Academic Level				
	Undergraduate	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Engineering - Agricultural - Civil - Environmental	1	3			4
Biology					
Ecology					
Fisheries, Wildlife and Forestry					
Argronomy					
Chemistry			1		1
Hydrology					
Resources Planning					
Law					
Economics	1	1			2
Geography					
Other					
TOTAL:	2	4	1		7